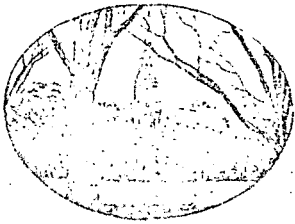


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## SPECIAL REPORT

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THE APOLLO 17  
FAR ULTRAVIOLET SPECTROMETER  
EXPERIMENT

Submitted by  
Wm. G. Fastie  
Principal Investigator

October, 1972

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Baltimore, Maryland 21218

The Apollo 17 Far Ultraviolet Spectrometer Experiment

by

Wm. G. Fastie

Department of Physics  
The Johns Hopkins University  
Baltimore, Maryland 21218

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II

### Abstract

The Apollo 17 command service module in lunar orbit will carry a far ultraviolet scanning spectrometer whose prime mission will be to measure the composition of the lunar atmosphere. Additional observations will include the spectral lunar albedo, the temporary atmosphere injected by the engines of the lunar exploration module, the solar system atmosphere, the galactic atmosphere and the spectra of astronomical sources, including the earth. A detailed description of the experimental equipment which observes the spectral range 1180 to 1680 Å, the observing program and broad speculation about the possible results of the experiment, are presented.

III

## I. Introduction

The Apollo 17 spacecraft, scheduled to be launched on December 6, 1972 will include in the scientific instrument module of the lunar orbiting service module, a large and highly sensitive far ultraviolet spectrometer which will cyclically scan the spectral region 1180 to 1680 Å every 12 seconds with a spectral resolution of 10 Å. A number of lunar, solar system and galactic observations will be made, the prime objective being to measure the lunar atmospheric emissions in an attempt to determine the density, composition, and temperature of the lunar atmosphere.

Our present knowledge of the lunar atmosphere indicates an atomic density level for all constituents below  $10^5$  to  $10^7$  atoms/cc at the lunar surface. At these levels of density scattering of solar radiation at the resonance lines of most of the atoms which are likely to be present in the lunar atmosphere requires the highest achievable instrumental sensitivity. The fact that the measurement of a very weak atmospheric emission must be made when the spacecraft is in sunlight and is also illuminated by the lunar surface, requires the use of very efficient optical baffling. The sensitivity requirement and the baffling requirement have

led to the design of a large Ebert spectrometer, which is described in Sec. III and which incorporates several new features. It should be noted that the instrumentation has been optimized for atmospheric observations in the far ultraviolet and although significant galactic and solar system observations can also be made, the instrument is not optimized for some of these objectives.

The technique of observing atomic resonance line reradiation of solar far ultraviolet flux provides a very sensitive method of detection of atmospheric atomic species. The method takes advantage of the very large solar flux, the high cross section for excitation at the atomic resonance lines and the long path lengths available in planetary atmospheres.

There are many operational and geometrical factors which affect the lunar atmosphere observing program. Several observing modes are required to obtain all of the data needed to determine the atmospheric parameters. For example we must observe the dark lunar surface beyond the sunlit terminator while the atmosphere above the surface is still illuminated and we must observe the lunar atmosphere at near  $90^{\circ}$  zenith angle and at other angles against the galactic background. The solar system observations and galactic observations require other observing modes. The manner in which these observations are accomplished is described in Sec. V.

## II. The Lunar Atmosphere

The most definitive information about the density of the lunar atmosphere has been obtained with cold cathode pressure gauges on the lunar surface (Johnson 1971). These measurements indicate that the maximum lunar atmospheric density on the illuminated side probably does not exceed  $10^7$  atoms per cc at the lunar surface and that the minimum density on the lunar dark side is greater than  $10^5$  atoms/cc. Thus the lunar surface is an exosphere with the lunar surface defining the exobase and therefore controlling the "temperature" of the atmosphere. More specifically, there are no collisions between the atmospheric molecules or atoms. Gravitationally trapped neutral particles leave the lunar surface with a velocity which is probably determined by the local lunar surface temperatures, travel in ballistic orbits with a typical flight time of a few hundred seconds and return to the lunar surface, where the process is repeated. Eventually these particles will be ionized by the extreme ultraviolet solar radiation and can then escape from the moon by spiraling about the magnetic field lines imbedded in the solar wind, if they do not first collide with the lunar surface and become neutralized by electron capture.

Because of the weak gravitational field of the moon the lighter atmospheric species have a chance to escape from the moon (the lunar escape velocity is 2.3 km/sec). In particular all hydrogen atoms which leave the lunar surface with the average velocity acquired from a 400°K surface (2.9 KM/sec) will not return.

Chemical reactions and gaseous adsorption at the lunar surface can also represent a sink for pulses of gases introduced on the moon. For example, the many tons of gas which have been introduced by the Apollo landings have undoubtedly been largely held in the lunar surface.

The sources of the lunar atmosphere are threefold; the solar wind, lunar degassing and radiogenic gases (argon and radon) formed by lunar radioactivity. A thorough discussion of the possible equilibrium concentrations of the lunar atmospheric species has been presented by Johnson (ibid).

The UVS experiment has been designed to optimize the observation of atomic hydrogen and Xenon by spending about

45% of each spectral cycle scanning the resonant emissions of these two species. Since protons are the main component of the solar wind we would expect an equilibrium concentration of H of about  $10^3$  atoms/cc at the lunar surface if most protons charge exchange at the lunar surface and escape. On the other hand if most of the protons charge exchange and form hydrogen molecules before leaving the surface they will not be detectable at 1216 Å (Ly  $\alpha$ ) with the UV spectrometer until they are dissociated in the atmosphere by extreme ultraviolet radiation. Primordial hydrogen atoms are certainly no longer present on the moon because of the ease with which they can gravitationally escape. Thus the observation of atomic hydrogen in the lunar atmosphere will determine the lunar-solar relationship which will be of significance in lunar surface geology as well as in developing concepts about the origin and maintenance of planetary atmospheres.

Optimization for Xenon detection at 1470 Å is planned on the basis that this heaviest of the naturally occurring gases would probably be the most resilient to the loss processes, which have reduced the primordial lunar atmosphere density to at least  $10^{-12}$  of the density at the surface of the earth. The solar wind Xenon source is at a level that the solar wind electromagnetic field will substantially remove it, (Johnson, *ibid*)



that is, solar wind Xenon ions which charge exchange and thermalize at the lunar surface and enter the atmosphere, are ionized by extreme ultraviolet solar radiation, and escape the moon by spiralling about the solar wind field lines. Thus the detection of Xenon in the lunar atmosphere would represent an important parameter in determining the moon's geological and atmospheric history.

Other atomic atmospheric species which might be detected by the UVS as resonance reradiation are carbon (1657 A), oxygen (1304 A), nitrogen (1200 A), and krypton (1236 A). The atmospheric species whose resonance lines are not within the UVS range are Helium (584 A), Neon ( 744 A), Argon (1048 A) and Radon (1786 A). The solar resonance reradiation detection method requires a solar emission line or solar continuum at the resonance line, and for Ne and Ar the sun is so weak that instrumentation to detect their resonance reradiation at lunar density levels is beyond the state of the art. Although Helium can be detected by resonance reradiation at 584 A, where the sun is relatively bright, at lunar density levels detection of this radiation requires much different photometric equipment which is not capable of measuring other atmospheric species at the level of detection of which the UVS is capable. Radon is

detectable by the resonance method, but the 3.8 year radioactive lifetime of Radon precludes its buildup in detectable quantities. Moreover, the Apollo 16 alpha particle spectrometer provides a more sensitive Radon sensor. Localized lunar Radon at density levels much below the UVS sensitivity levels has been reported (Gorenstein 1972).

Thus the UVS experiment is capable of searching for all of the atomic species for which there is a reasonable chance of detection with the exception of Helium. Any carbon, nitrogen and oxygen which may be released in the lunar atmosphere would probably become bound in the surface by chemical reaction or by adsorption after a few collisions with the surface. These species will undoubtedly be present at least for a few hours in the lunar atmosphere as products of combustion of the lunar lander engine and will probably be detected by the UVS for several lunar orbits during the mission.

### III. Description of Instrumentation

#### A. General Principles

Because most of the expected UV emissions from the lunar atmosphere will be very weak, we have attempted to optically and electronically optimize the flight spectrometer.

It is well known (e. g. Pastie 1952) that the signal in photo-electrons/sec delivered by a Littrow or near Littrow grating spectrometer is given by the formula

$$S_{\lambda} \text{ (pe/sec)} = k A_g \frac{L}{F} Q_{\lambda} T_{\lambda} \quad (\text{Eq. 1})$$

where  $k$  is a constant which includes the source function, the slit width and the spectral dispersion

$A_g$  is the grating area

$L$  is the slit length

$F$  is the spectrometer focal length

$Q_{\lambda}$  is the quantum efficiency of the detector

$T_{\lambda}$  is the optical transmission

For the Apollo 17 spectrometer we have employed the largest available diffraction grating which was specially ruled for this purpose by Bausch and Lomb Optical Company and which has an optical efficiency at least twice as good as previously available gratings. We have employed the largest available photomultiplier tubes with high quantum efficiency and have designed an optical system which permits the use of a slit length to focal length ratio which provides almost a threefold improvement in output signal. By choosing a grating with the highest possible dispersion, and employing a wide spectral slit width, (which is a compromise between sensitivity and spectral resolution)

we have maximized the value of  $k$ . We have also employed an electronic detector system which counts the photoelectron pulses and discriminates against electronic noise and dark current.

As a result of these several factors we have produced an instrument for the Apollo 17 mission which is at least an order of magnitude more sensitive than previous far ultraviolet spectrometers which have been used for rockets, satellites and planetary flyby missions to study planetary atmospheres.

#### B. Description of Optical-Mechanical System

Figure 1 is a plan view of the spectrometer optical system. This type of instrument was conceived by Herman Ebert (1889), buried by Kayser (1900) and resurrected in 1949 (Fastie 1952 a, b). It was first used in a space experiment in 1960 (Fastie et al. 1962) and has been widely used by many space scientists in the past decade (e. g. Barth (1969a), Barth et al. (1969b), Crosswhite et al. (1962), Donahue and Fastie (1964), Fastie et al. (1964) ). In addition to its high optical efficiency, the Ebert optical system is optically simple, can achieve high spectral resolution (Fastie et al. 1958) and has a folded optical system which provides a compact instrument with a high degree of mechanical stability; all of which qualities enhance the attractiveness of the system for space applications.

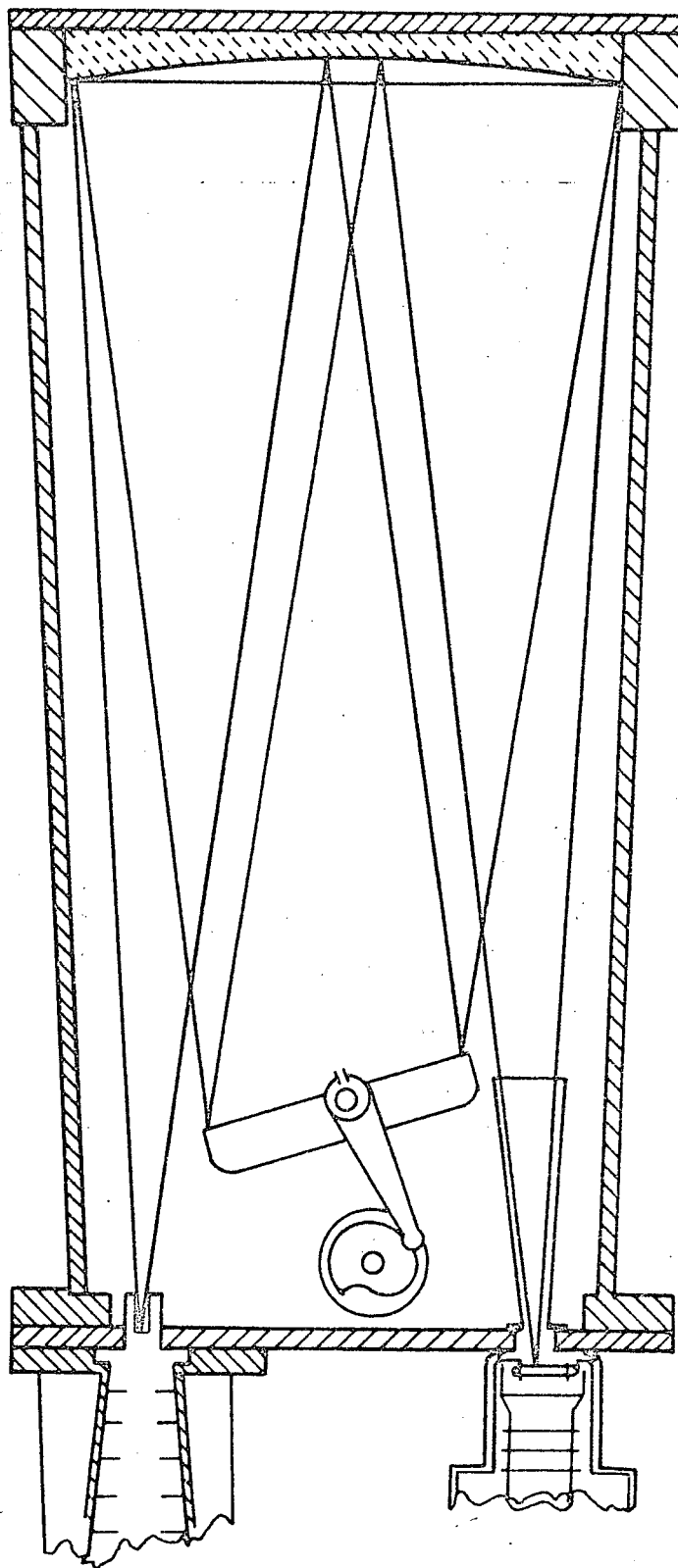


Fig. 1 Plan View of Spectrometer Optical System

As shown in Fig. 1 light entering the slit reflects from one-half of the spherical Ebert mirror and goes to the diffraction grating. The diffracted light from the grating goes to the other half of the Ebert mirror which focuses the spectrum at the exit slit plane. The monochromatic light passes through the slit and strikes the photocathode of the detector. The entrance slit is longer than the exit slit, and the long spectral image thus produced is "folded" by the exit slit mirrors to increase the monochromatic photon density passing through the slit.

The grating is mounted in a housing which contains shafts on each end about which the grating can rotate. Two bearing plates which are mounted to the slit plate provide ball-bearing mounts to support the grating shaft. A synchronous motor, gear reducer and cam mechanism to cyclically rotate the grating through its spectral range are also supported on the slit plate. The cam is designed to scan linearly in wavelength range 1180 to 1680 Å at about 75 Å per second except for two 50 Å regions centered on 1216 Å (atomic hydrogen) and 1470 Å (Xenon) which are linearly scanned at 16.6 Å/sec. An optical fiducial marker monitors each cam rotation so that wavelength synchronization for all wavelengths can be accomplished throughout the mission.

Table I.

Optical and Optical-Mechanical Parameters

Focal Length (F)	500 mm
Spectral Resolution (including aberrations)	11.5 A
Slit Width	2 mm
Entrance Slit Length	57 mm
Grating Area	104 cm <sup>2</sup>
Grating Spacing	3600 grooves/mm
Spectral dispersion at exit slit	5 A/mm
Scan period	12 sec
Total weight	37 lb.
Rectilinear volume (including baffle)	1 cu. ft.
Total power requirements	7 watts
Telemetry rate	160 bits per sec
Optical Transmission (typical)	
1216 A	20%
1470 A	25%
1608 A	20%
Quantum Efficiency (typical)	
1216 A	12%
1470 A	10%
1608 A	4%
Photocathode diameter	24 mm
Dark count rate (after pulse discrimination)	.5 counts/sec
Peak sensitivity for sq. cm col emission rate of 10 <sup>6</sup> photon/sec (1 Rayleigh)	75 photoelec/sec

Photoelectron counts are accumulated for 0.1 second and the count is transmitted to the spacecraft data system as a 16 bit binary word. The optical, optical-mechanical and electrical properties of the instrument are listed in Table I. Figure 2 is an exploded isometric view of the spectrometer.

The external entrance slit baffle is shown in Fig. 3. The principle of this type of baffle has been previously described (Fastie 1967). In summary, the inner section of the baffle is positioned so that light scattered by it must also be scattered by the entrance slit jaws or by the inner parts of the spectrometer in order to reach the grating. The second section of the baffle is angled so that light scattered from it cannot reach the entrance slit unless it is scattered from the inner section, and so on. This type of baffle is so effective that it cannot be experimentally evaluated in air because of Rayleigh scattering. In a rocket test of a preprototype of the Apollo instrument, studies were made at solar angles which were smaller than will be encountered in lunar orbit. No scattered light was detected.

The exit slit mirror system not only increases the monochromatic signal delivered to the detector photocathode but also provides means by which loss of resolution due to curvature of spectrum can be reduced to a negligible value. The design of



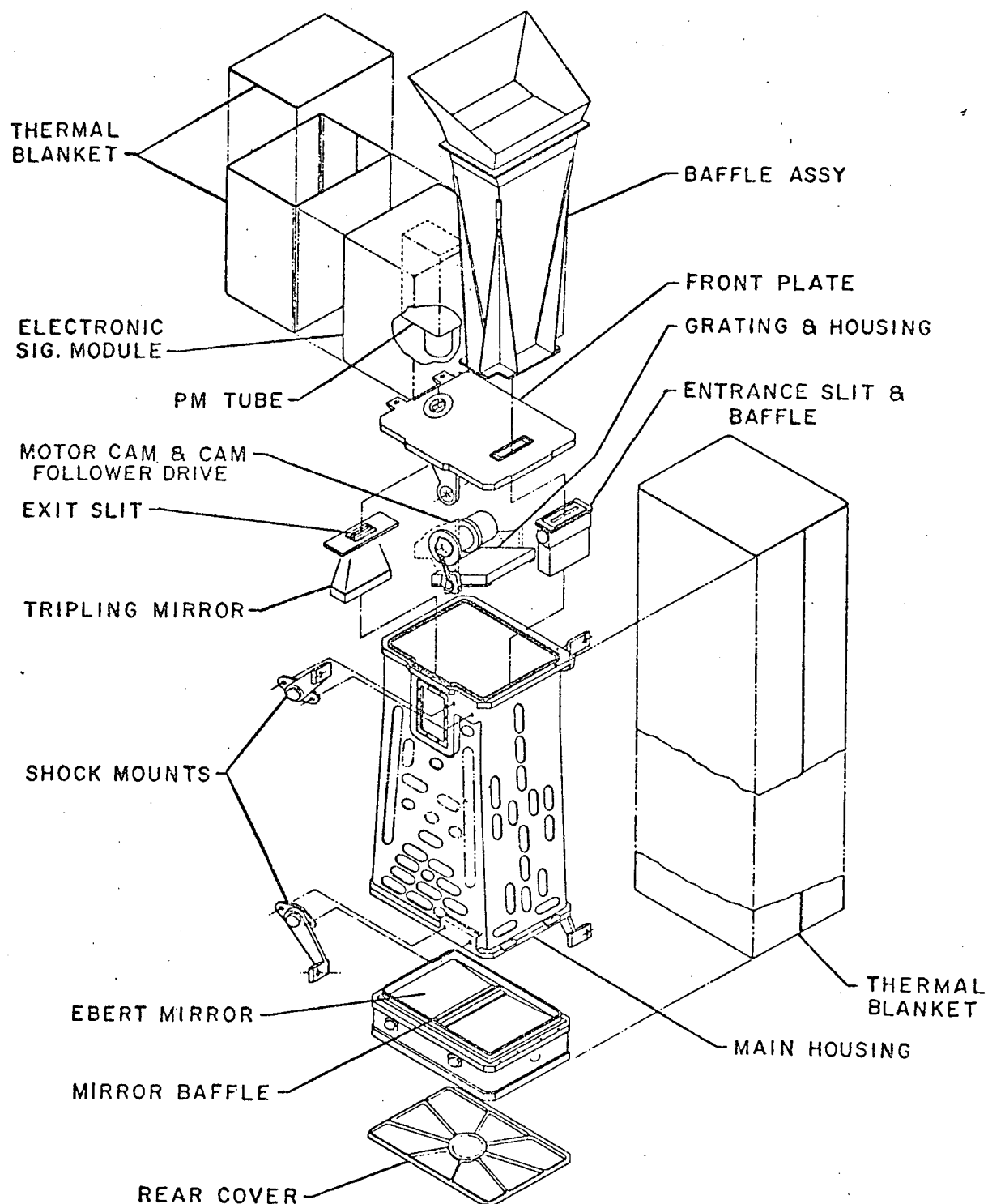


Fig. 2 Exploded Isometric View of Spectrometer

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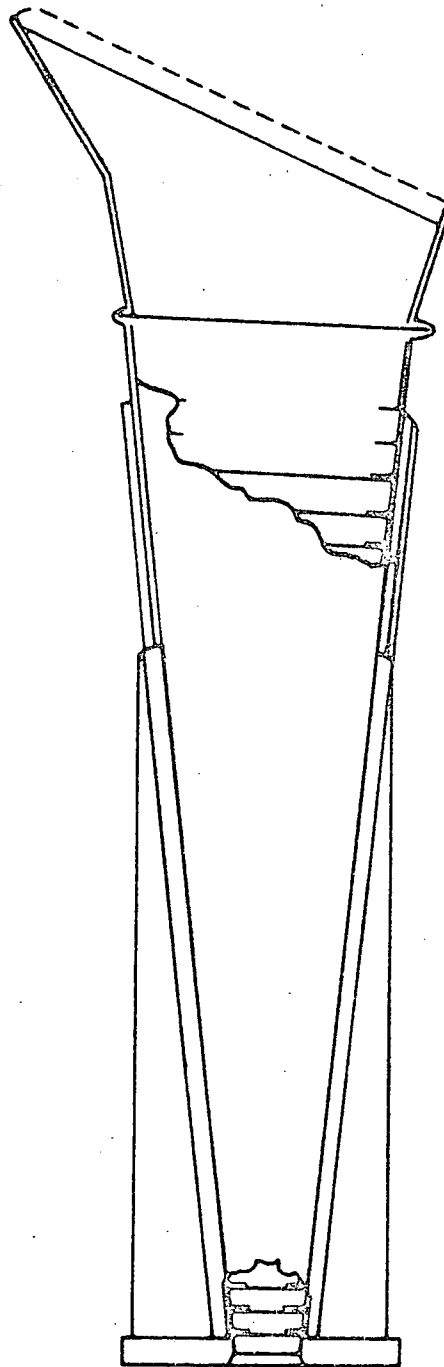


Fig. 3 External Entrance Slit Baffle

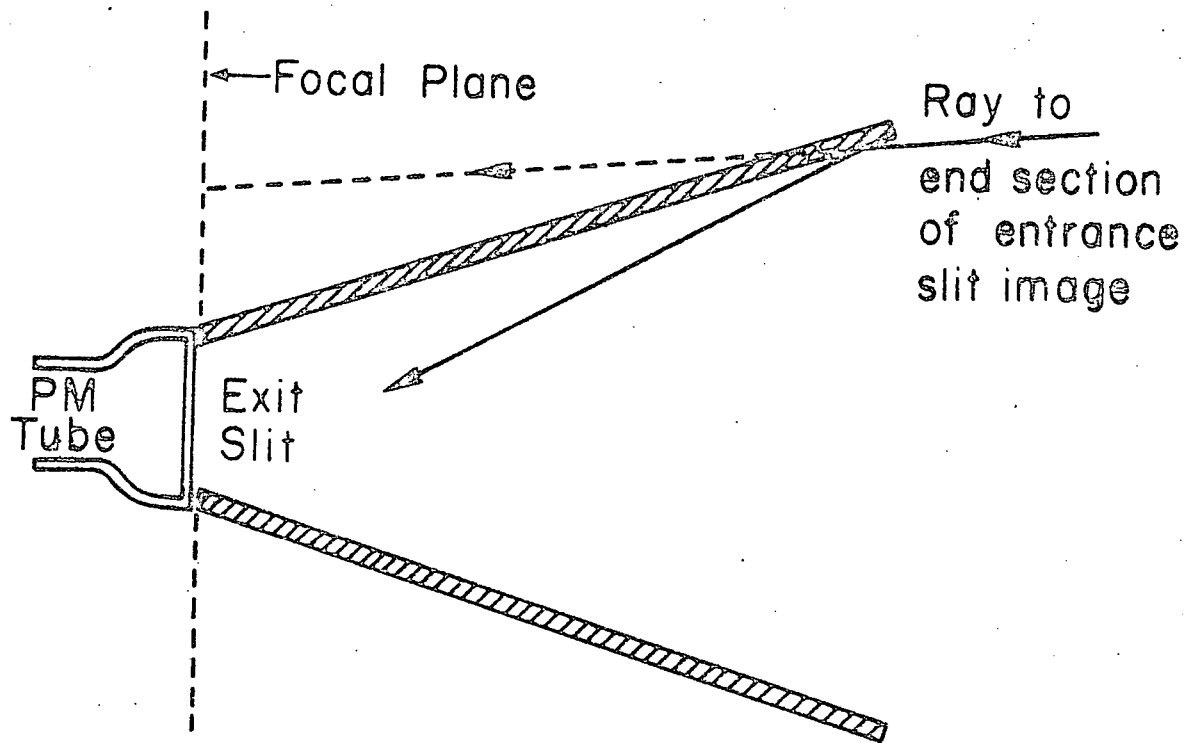


Fig. 4 Elevation View of Exit Slit Mirrors

the exit slit system and the description of the required adjustments have been presented elsewhere (Pastie 1972). In summary, the exit slit mirrors are placed at opposite ends of the 2.2 cm long exit slit at such an angle that they reflect the end sections of the 57 mm long entrance slit image onto the exit slit as shown in an elevation view in Fig. 4. In order to keep this reflected image in focus, the entrance slit must be in three linear sections as shown in Fig. 4 with the ends of the entrance slit inside the focal plane. The exit slit mirrors are used at very high angles of incidence where evaporated Al which has been oxidized in air exhibits high reflectivity in the far ultraviolet (Hunter et al. 1969).

The Ebert mirror and the diffraction grating are coated in vacuum with Al and overcoated with  $\text{Mg F}_2$  (Hunter et al. 1969) to provide a high optical efficiency.

The signal in photoelectrons per second which will be produced by a monochromatic source which has sufficient angular extent to fill the monochromator optical system is given by the equation:

$$S \text{ (pe/sec)} = B_{\lambda}^s \frac{A_s A_g}{F^2} Q_{\lambda} T_{\lambda} \quad (\text{Eq. 2})$$

where  $B_{\lambda}^s$  is the source brightness in photons per second per sq cm per steradian and the other quantities have been defined earlier.

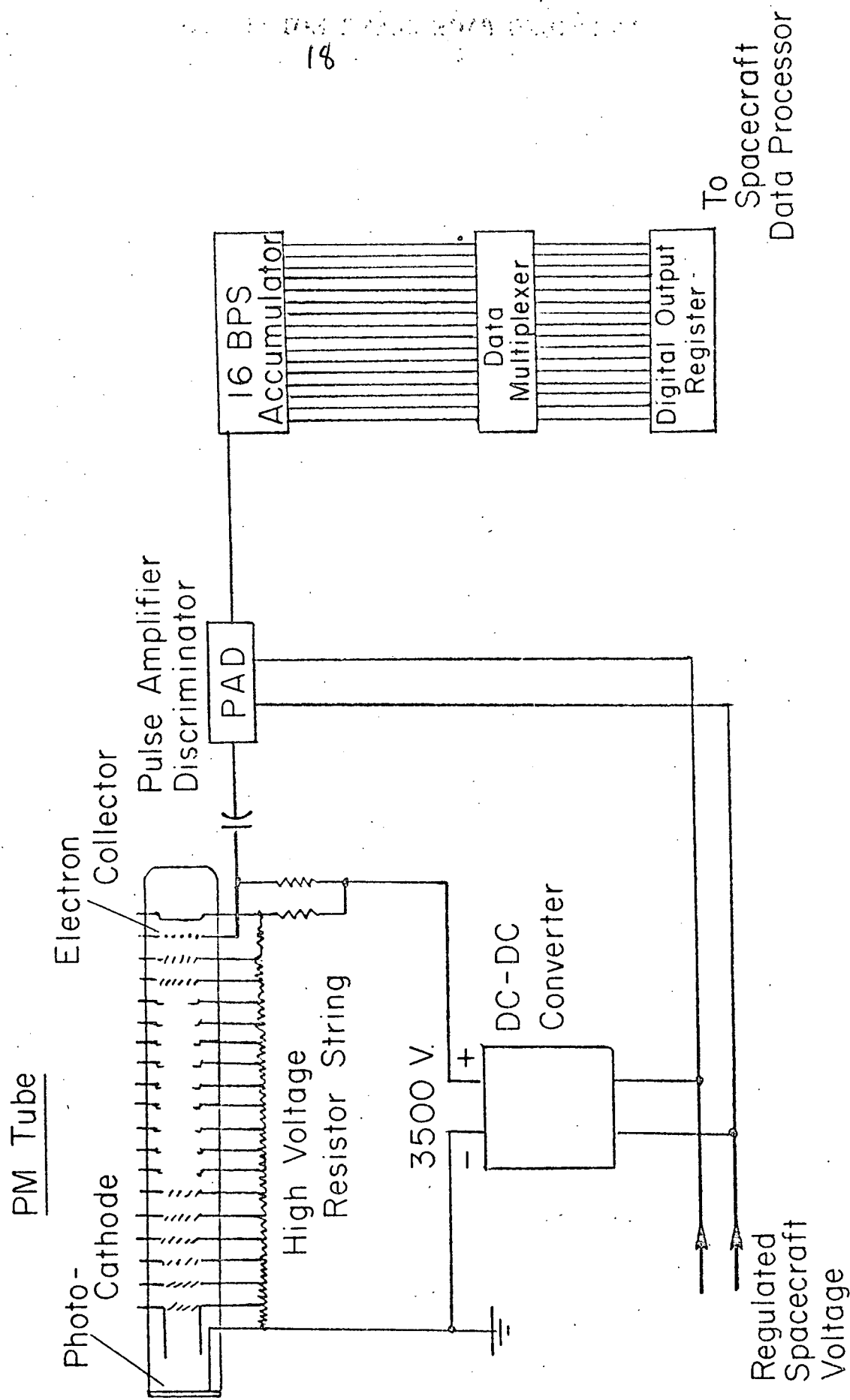


Fig. 5 Photomultiplier Detector Electronic Schematic Diagram

An atmospheric source which is optically thin and which emits over a solid angle of  $4\pi$  steradians and which appears to have a brightness  $B_{\lambda}^S$  will emit  $4\pi B_{\lambda}^S$  photons per sq cm column. Conversely a sq cm column emission rate of  $10^6$  photons per second will appear to have a surface brightness of  $\frac{10^6}{4\pi}$  photons/sec. Aeronomists use the brightness unit of Rayleigh to define a source of  $10^6$  photons/sec/sq cm col.

### C. Electronic Circuitry

A schematic diagram of the photomultiplier tube circuitry is shown in Fig. 5. Electrons which are produced by photons striking the photocathode are multiplied by the dynode string to produce a nominal pulse of  $5 \times 10^6$  electrons in about 10 nanoseconds at the collector. This electron pulse is rejected by the pulse amplifier and discriminator circuit if it contains less than  $5 \times 10^5$  electrons, otherwise it is converted to a low impedance square wave voltage pulse with about 1.8 microsecond width. Each pulse is stored in a 16 bit counter. The discrimination greatly reduces electronic noise and provides a true measure of the PMT dark count which is about 0.5 counts/sec. Each tenth second the accumulated stored count is transferred to a second register, and during the next tenth second the second register is read out by the spacecraft

data system which either telemeters the signal immediately to earth receiving stations or, if the spacecraft is in earth shadow, stores the information on tape for transmission to earth during a portion of the lunar orbit when the earth is in view.

An optical fiducial detector associated with the synchronous wavelength drive cam is used to provide a signal to begin the photoelectron count at precisely the same wavelength each spectral scan. This technique provides an opportunity to sum any desired group of the approximately 25,000 spectra which will be acquired during the mission without loss of spectral resolution. During the 0.5 second flyback period of the cam follower arm a five word recognition pattern is transmitted which simplifies computer handling of the data.

Further information is separately transmitted about instrument status, such as supply voltage levels and temperature. A shutter is part of the spacecraft system and has been provided to protect the spectrometer from direct sunlight and from spacecraft attitude control jets. This shutter, special spacecraft attitudes and instrument power will be controlled on board by the astronaut crew who will verbally transmit these aspects of instrument status to the control center at Houston. The astronaut crew consists of Commander Gene Cernan, Commander Roland Evans and Dr. H. H. Schmitt.

During a 1.8 microsecond period after the pulse amplifier discriminator has received a pulse from the photomultiplier tube, it is incapable of responding to another pulse. Therefore when the photon flux becomes large enough that there is a significant probability that more than one photoelectron will occur during a 1.8  $\mu$ s period, the observed count rate  $C_o$  is less than the true count rate  $C_T$  according to the statistical equation

$$C_T = \frac{C_o}{1 - C_o \tau}$$

or

(Eq. 3)

$$\frac{1}{C_T} = \frac{1}{C_o} + \tau$$

where  $\tau$  is the dead time of the circuit.

For  $\tau = 1.8 \mu$ s and for a very large signal the observed count will approach 555,535 counts per second. For example for  $10^7$  true counts per second, the observed count rate will be 526,420. On the other hand the observed count rate will track the true count rate very closely, at low intensity levels, departing by only 1% at 5500 counts per second.

Thus the circuitry provides a linear response at the low count levels expected from the lunar atmosphere but can provide an extended range to measure the very large solar signal reflected from the moon. The 16 bit counter has a maximum capacity of 65,536 counts just above the maximum counting capacity of the circuitry for a 100 ms period.



#### IV. Sensitivity of Resonance Reradiation Method

The number of photoelectrons detected by the Apollo 17 UVS resulting from atomic resonance reradiation of an optically vertical emitting column is given by the equation

$$S \text{ (photoelectrons/sec)} = F_S^\lambda \sigma_\lambda N_o H E_\lambda \quad (\text{Eq. 4})$$

where  $F_S^\lambda$  is the solar flux in photons/cm<sup>2</sup>/sec/Angstrom

$\sigma_\lambda$  is the atomic cross section

$N_o$  is the density at the base of the column

H is the scale height of the atomic specie \*

$E_\lambda$  is the instrumental optical and electronic conversion efficiency.

The parametric values for the atmospheric atoms of interest are listed in Table II. From the spacecraft orbital altitude of 100 KM, at which height virtually all of the lunar Xenon is below the spacecraft, a vertically downward observational path provides a Xenon signal of  $2.7 \times 10^{-4}$  photoelectrons per unit Xenon density at the lunar surface. If we assume that the background count rate from all sources (dark count, solar scattered radiation, galactic scatter from the darkside lunar surface) is 2 pe per second, assume a total Xenon line observation time of 100 seconds and

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\* The exospheric scale height is the vertical distance above the bottom of the column over which the number density of the observed specie decreases to 1/e of its value at the base of the column. In a constant gravitation field H can be calculated from the relationship  $H = \frac{kT}{mg}$  where

k is Boltzmann's constant, T is the atmospheric temperature at the base of the exosphere (in this case the lunar surface) m is the atomic mass and g is the gravitational constant.

Table II.

## Sensitivity to Atomic Species in Lunar Atmosphere

Atom	$\lambda(A)$	Solar Flux (photon/cm <sup>2</sup> /sec/A)	$\sigma_{\lambda}^{15}$ (x10 <sup>15</sup> )	Scale Height (CM)	Optical Efficiency (x10 <sup>5</sup> )	Fraction of Atoms below 100 KM	Count Rate for Unit Surface Density	Minimum Detectable Concentration at Surface
Hydrogen	1216 A	$4 \times 10^{11}$	5.5*	$3 \times 10^8$	8.0	.033	1.75/sec	1
Xenon	1470 A	$3 \times 10^8$	5.0	$2 \times 10^6$	8.3	.99	$3.7 \times 10^{-4}$ sec	540
Oxygen	1304 A	$1.7 \times 10^{10}$	.47	$1.9 \times 10^7$	8.5	.41	$5.3 \times 10^{-3}$	27
Nitrogen	1200 A	$2 \times 10^8$	4.5	$2.1 \times 10^7$	7.8	.38	$5.6 \times 10^{-4}$	260
Carbon	1657 A	$5 \times 10^{10}$	4.1	$2.5 \times 10^7$	2.5	.33	$4.3 \times 10^{-2}$	34
Krypton	1236 A	$4 \times 10^7$	2.3	$3.5 \times 10^6$	8.1	.94	$2.5 \times 10^{-5}$	6000

\* Based on Eq. 5, T = 100 seconds, S/N = 1, B = 2 counts/sec, except for Hydrogen B = 200 counts/sec. Assumes observation of column below spacecraft against dark terminator.

use the criterion that the signal to noise ratio must be one for positive detection, we can calculate the expected minimum detectable Xenon concentration from the statistical formula

$$\frac{S}{N} = \frac{S \text{ (pe/sec)} T}{\sqrt{(S + B) T}} \quad (\text{Eq. 5})$$

where B is the background count rate and T is the observation time. For the assumed conditions the minimum detectable Xenon concentration at the lunar surface would be about 500 atoms/cc, about 4 orders of magnitude below the present upper limit.

For hydrogen, the scale height is much greater than the spacecraft altitude which means that the hydrogen density below the spacecraft is substantially constant. Because the sun is very bright at the hydrogen resonance wavelength, the minimum detectable atomic hydrogen signal against a background count of 2 per second would be 0.1 atoms per cc at the lunar surface; however at the hydrogen wavelength the galactic signal scattered from the moon's darkside is expected to produce a background count of about 500 counts/sec which, on the basis of Eq. 5 gives a minimum detectable hydrogen concentration of about 1/cc, which is well below the expected minimum concentration.

A 30 times larger signal from hydrogen in the lunar atmosphere can be obtained by observing outward from the moon, but this mode of

observation must be made against the full galactic background of about 200 Rayleighs which results in a higher minimum detectable limit.

The expected minimum detectable limits for the atomic constituents of the lunar atmosphere are listed in Table II.

It should be emphasized that the resonance reradiation method of detection provides an absolute measurement. All of the parameters of Eq. (5) are known or can be measured to a high degree of accuracy; that is  $F_s^\lambda$ , the solar flux in the far ultraviolet is well known, and will in fact be remeasured with a rocket borne spectrometer during the Apollo 17 mission, the atomic resonance scattering coefficient  $\sigma_\lambda$  has been accurately determined in the laboratory for the relevant gases, and the instrumental factor  $E_\lambda$  has been the subject of very careful measurements during the preparation for the mission.

#### V. Observing Program

The Apollo 17 spacecraft will spend most of its time in lunar orbit at a 100 KM altitude with the scientific instrument module axis maintained fixed with the local vertical. The spacecraft nose will either be pointed in the direction of flight or  $180^\circ$  to that direction. The UVS is mounted in a fixed position

C

in the spacecraft with its optical axis pointed  $23^{\circ}$  forward of the SIM bay axis and  $18^{\circ}$  to starboard and with the entrance slit aligned approximately perpendicular to the nadir and to the direction of flight. The lunar orbital direction is such that the spacecraft flies into darkness on the lunar sunrise terminator which is visible from the earth throughout the mission. Thus when the spacecraft nose is pointed in the direction of flight the entire field of view of the UVS is directed at the unilluminated lunar surface before the spacecraft crosses the lunar sunrise terminator and can observe the illuminated atmosphere against the dark lunar background until the spacecraft enters the shadow which occurs about 600 km beyond the terminator, providing 400 seconds of observation time and about 30 spectral scans with varying shadow height. The shadow height variation provides a means of determining the scale height of the various atmospheric species.

As the spacecraft emerges from the dark and crosses the lunar sunset terminator another 400 seconds of lunar atmospheric observation will be possible, and will be obtained with minimum interference from the illuminated lunar surface when the spacecraft nose is pointed  $180^{\circ}$  to the direction of motion.

Because of the large temperature differential between the dark and the illuminated surface, it is anticipated that the lunar sunrise terminator (spacecraft sunset terminator) will show a denser atmosphere and lower atmospheric temperature than observed at the lunar sunset terminator.

During the brightside crossing, the UV data, combined with solar data obtained from a rocket during the mission will provide information about the far UV lunar albedo and its variations. These measurements will be compared with laboratory measurements currently in progress on lunar dust samples, and with samples returned from Apollo 17.

During lunar orbit, the spacecraft will occasionally be oriented so that the UV spectrometer observes an emitting column at a variety of lunar aspect angles including one parallel to the lunar surface, which enhances the atmospheric signal for carbon, nitrogen and oxygen by about a factor of 10, but against a stellar background which will be measured during the return flight to earth.

When the spacecraft is in shadow, the spacecraft can be oriented to permit observations of the hydrogen atmosphere which extends to several lunar radii. This observation will permit a determination of the lunar hydrogen scaleheight. From within the

shadow it will also be possible to observe the solar atmosphere at distances much closer to the sun than have previously been possible, permitting a study of the extended solar atmosphere and of the zodiacal light.

During the return flight to earth a large number of astronomical objects, including the earth and the moon, will be observed. Of particular interest will be a careful search for a hydrogen geotail and a study of the extended solar atmosphere.

#### Acknowledgement

A very large number of people have contributed to the development, construction and testing of the Apollo 17 UV spectrometer, only a few of whom can be listed here. Professors H. Warren Moos, Paul D. Feldman, Richard C. Henry of this laboratory, Professors Charles A. Barth and Gary Thomas, University of Colorado and Professor Thomas M. Donahue, University of Pittsburgh are co-experimenters. Most of the design, construction and testing was managed by the Johns Hopkins University Applied Physics Laboratory, under the leadership of Dr. R. B. Kershner, assistant director. Mr. Ted Wyatt served as project engineer, Mr. R. Donald Wagner as electronic engineer, Mr. Edward Marshall as test director and Mr. Clyde T. Holliday performed most of the optical assembly and

adjustment. Major industrial suppliers were Ray Lee Instruments, Inc., Pikesville, Maryland (design and optical-mechanical parts), Bausch and Lomb Optical Co. (gratings), Electro Mechanical Research, Princeton, New Jersey (photo detectors), and Muffoletto Optical Co., Baltimore, Maryland (mirrors). Mr. Louis McFadin, Manned Spacecraft Center, Houston, is the experiment manager, and Mr. Nat Hardee, assisted by Mr. Paul Blackmon, MSC, Houston is science experiment manager. Mr. James Diggins, Goddard Space Flight Center served as optical consultant to MSC and also conducted calibration checks of the UVS with the Vacuum Optical Bench facility at GSFC. In this laboratory, much of the scientific studies and calibration work was performed by Professors Donald E. Kerr and H. M. Crosswhite, Dr. R. C. Schaeffer, Mr. L. J. Hruska, Mr. Robert Richardson, Mr. M. D. Chedester, Mr. Heinz Weiser, Mr. Robert Lucke and Mr. L. W. Green.



## References

- Barth, C. A. : 1969a, 'Planetary Ultraviolet Spectroscopy',  
Appl. Opt. 8, 1295.
- Barth, C. A. et al. : 1969b, 'Mariner 6: Ultraviolet Spectrum of  
Mars Upper Atmosphere', Science 165, 1004-1005.
- Crosswhite, H. M., Zipf, E. C., Jr., and Fastie, W. G. : 1962,  
'Far-Ultraviolet Auroral Spectra', J. Opt. Soc. Am. 52, 643.
- Donahue, T. M., and Fastie, W. G. : 1964, 'Observation and  
Interpretation of Resonance Scattering of Lyman  $\alpha$  and OI  
(1300) in the Upper Atmosphere', in P. Muller (ed.) Space  
Research IV (Proceedings of the Fourth International Space  
Science Symposium Warsaw, June 3-12, 1963).
- Fastie, W. G. : 1952a, 'A Small Plane Grating Monochromator',  
J. Opt. Soc. Am. 42, 641.
- Fastie, W. G. : 1952b, 'Image Forming Properties of the Ebert  
Monochromator', J. Opt. Soc. Am. 42, 647-651.
- Fastie, W. G., Crosswhite, H. M., and Gloersen, P. : 1958,  
'Vacuum Ebert Grating Spectrometer', J. Opt. Soc. Am. 48,  
106-111.
- Fastie, W. G., Crosswhite, H. M., and Zipf, E. C., Jr. : 1962  
'Far-Ultraviolet Auroral Spectra', J. Opt. Soc. Am. 52, 643.
- Fastie, W. G., Crosswhite, H. M., and Heath, D. F. : 1964,  
Rocket Spectrophotometer Airglow Measurements in the Far  
Ultraviolet', J. Geophys. Res. 69, 4129.

References - Cont'd.

- Fastie, W. G. : 1967, 'Ultraviolet Measurements in Planetary Atmospheres', Appl. Opt. 6, 397.
- Fastie, W. G. : 1972, 'Exit Slit Mirrors for the Ebert Spectrometer', Appl. Opt. 11, 1960.
- Gorenstein, Paul, and Bjorkholm, Paul: 1972, 'Detection of Radon Emanation From the Crater Aristarchus During Apollo 15', submitted to Science.
- Hunter, W. R., Osantowski, J. F., and Hass, G. : 1969, 'Reflectance of Aluminum Overcoated with  $\text{MgF}_2$  and LiF in the Wavelength Region from 1600 Å to 3000 Å at Various Angles of Incidence', Annual Meeting of Optical Society of America, Chicago, Illinois, 21-24 Oct. 69.
- Johnson, Francis S. : 1971, 'Lunar Atmosphere', Rev. Geophys. and Space Phys. 9, 813.